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(54) PROCESS AND ARRANGEMENT FOR AUTOMATIC DETERMINATION OF PARALLAX

(71) We, ERNST LEITZ WETZLAR GMBH, of 6330 Wetzler, Postfach 2020, German Federal Republic, a limited liability company organised under the laws of the German Federal Republic, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:–

The present invention relates to a process and to an apparatus for the automatic determination of parallax in a stereoscopic optical system.

In stereoscopic optical systems, it is desired that the parallax between two partial images is determined automatically. This applies for example to base range finders or to the evaluation of aerial stereo-pictures. For this, different systems for the optic-electrical scanning as well as for the further processing of the electrical signals arising in such circumstances have already been proposed.

One such known arrangement is shown in Fig. 1, in which the fundamental of the arising signals is utilized. Two lenses 10 and 11, which determine the light channels, image an object (not shown) by way of deflecting mirrors 12, 13, 14 and 15 on an optical structure 16, which is moved perpendicularly to the optical axes 18 and 19 by drive means 17′ energised by an electrical signal generator 17. Associated with each optical axis is a photo-electric receiver 20 and 21, which converts into electrical signals light components which have passed through the optical structure 16. A phase discriminator 22 and 23, controlled by a reference signal derived from the generator 17, is connected behind each receiver 20 and 21, and the output of the discriminator 22 associated with the first channel is connected by way of a regulator 24 with the drive means 17′, while the output signal of the discriminator 23 acts by way of a regulator 26 on a displacing mechanism 25 for effecting pivotable displacement of the mirror 15.

The mode of operation of this arrangement is such that the first channel determines the spatial phase difference and by way of the regulator 24 displaces the mean position of the optical grating until its output signal has become zero. The phase discriminator 23 in this case indicates the parallax. The resultant parallax is equalized to zero by way of the regulator 26 and the drive 25 of the mirror 15.

In known arrangements such as that which has been described above with reference to Fig. 1, it is disadvantageous that two regulating circuits are needed, which are coupled with one another by way of the optical grating.

Described in United States Patent Specification 3 710 124 is a process which proceeds from the fundamental and the second harmonic. The disadvantage of what is described there lies therein that, as can be shown, the accuracy of the measurement result depends on the accuracy with which the amplification is adjusted, which in turn depends on the respective amplitudes of the fundamental and the second harmonic.

According to one aspect of the present invention there is provided a process for automatically determining parallax in a stereoscopic optical system provided with movable optical structure means, the process comprising the steps of deriving two first electrical signals from optically distinguishable light fluxes received from the structure means, differentiating each of the two first signals, multiplying each differentiated signal derived from a respective one of the first signals by the respective other first signal to derive respective product signals, subtracting the respective product signals from one another to derive a difference signal, multiplying the difference signal by a reference signal related to motion of

the optical structure means to derive an output signal, and applying the output signal to at least one of an indicator device for indicating the parallax and a servo-device for reducing the parallax.

Preferably, the signal derived from the last-mentioned multiplication step is smoothed. To advantage, the gained electrical input signals are each filtered. Moreover, the signal components of the signals to be subtracted or of the signal gained by subtraction containing no measurement informations, as for instance a.c.-components or noise components, may be eliminated.

According to another aspect of the present invention, there is provided apparatus for automatically determining parallax in a stereoscopic optical system provided with movable optical structure means, the apparatus comprising two photo-electric receivers to generate respective first electrical signals in response to optically distinguishable light fluxes received from the optical structure means, two differentiating devices each to differentiate a respective one of the first signals, two multiplier devices each connected to receive the differentiated signal from a respective one of the differentiating devices and to receive the respective first signal from the respective other photo-electric receiver, a subtractor device to derive a difference signal by subtraction from one another of the output signals of the respective multiplier devices, means to generate a reference signal related to motion of the optical structure means, a further multiplier device to multiply the difference signal by the reference signal, and at least one of an indicator device for indicating parallax and a servo-device for reducing parallax connected to output means of the further multiplier device. However, a generator provided with corresponding outputs can also be present for this. The lastmentioned multiplying stage may be in the form of a phase-sensitive rectifier, or an electronic switch or a ring modulator.

As has become evident, the phase difference, which results from the parallax and which in a closed regulating circuit is to be reduced to zero, for example by way of an optical setting member, may be regulated independently of either the respective amplitudes of the input signals or of their relative phase position.

Let it be assumed, as example for explanation, that the process is to be applied in connection with a base range finder, in the two channels of which optical structures are mounted in image planes and oscillate with an amplitude of a quarter structure period. At the photo-electric receivers arranged behind the structures, electrical signals S_1 and S_2 then occur, which are composed of a fundamental component $\sin \omega t$ and a harmonic component $\cos 2\omega t$. In the ideal case, they have the form

$$S_1(t) = C_1 (\cos \Phi \,.\, \sin \omega t + K \sin \Phi \,.\, \cos 2\omega t)$$

$$S_2(t) = C_2 (\cos [\Phi + \psi] \,.\, \sin \omega t + K \sin [\Phi + \psi] \cos 2\omega t);$$

in that case, C_1 and C_2 are amplitude factors, which by regulation are to be maintained at constant as possible and of equal value. The factor K corresponds to the ratio of harmonic to fundamental amplitude and has approximately the value 0.5 with an amplitude of oscillation of the grating of about one quarter division period. Φ is an arbitrary initial phase, which results from the accidental phase position between the image of the measured object and the structure. ψ is the phase difference resulting from the parallax between the two channels.

It now matters to find that combination of the two mentioned signals, which in the case of equalisation is independent of the amplitudes of the two signals and of their phase position Φ. Moreover, this combination should be realizable with the use of the fewest possible expensive means.

According, there is used the mathematical expression

$$S_c = (S_1 \,.\, \dot{S}_2 - S_2 \,.\, \dot{S}_1) \cos \omega t,$$

wherein the dots arranged above the letters indicate that time-differentiated signals are concerned. Through insertion of appropriate values in the above expression, there results

$$S_c = - 3/4\, \omega K C_1 C_2 \sin \psi$$

For $\psi = O$, $S_c = O$ as desired, namely independently of the magnitudes Φ, C_1 and C_2.

For $\psi = O$, by contrast, the amplitudes magnitudes are effective and, since S_c is proportional to $\sin \psi$, a symmetrical equalisation, correct in sign is possible in the region $\psi = \pm 180°$.

The present invention is particularly applicable to the determination of parallax in a binocular optical system.

An embodiment of the present invention will now be more particularly described by way of example with reference to the accompanying drawings, in which:–

Fig. 1 shows a schematic diagram of a known arrangement which has been described previously; and

Fig. 2 shows a schematic diagram of an arrangement for automatically determining the parallax in an optical system in accordance with an embodiment of the present invention.

Referring now to Fig. 2 of the accompanying drawings, the two input signals S_1 (t) and S_2 (t), which are derived by way of two lenses 10 and 11 and deflecting mirrors 12 to 15 of a base range finder and by way of a movably mounted optical structure 16 – which is oscillatorily displaced by drive means 31 – and two photo-electric receivers 20 and 21 from the optical ray paths in dependence on the position of an object (not shown), are applied to respective signal differentiating stages 32 and 33. The output signals from the differentiating stages are each applied together with the input signal derived from the respective other differentiating stage, to multiplication stages 34 and 35. The output signals from the stages 34 and 35 are subtracted from one another in signal subtractor means 36 and the resulting difference signal is multiplied in a further multiplication stage 37 by a reference signal, which is derived with reference to the relative motion of the optical structure 16. The signal S_c thus obtained is the desired setting signal, which – if required or desired – may be smoothed by a smoothing stage 38 (indicated in broken lines), which is connected to the output of the stage 37 and which may be in the form of an integrator circuit. The setting signal S_c is applied to a mechanism 25, which is disposed in a parallax correcting circuit and which pivotably displaces a mirror 15, and/or to an indicator device 39 for indicating the parallax error.

The reference signal may be derived in a number of different ways. For example, it may be derived from a signal generator 42, which controls the drive means 31 and which is provided with a further output from which the desired reference signal is obtained. Another possibility is to derive the reference signal from the signal applied to the drive means 31 by way of a differentiating stage 43 (which is shown in Fig. 2 in broken lines). It is also possible to obtain the reference signal by way of an additional photo-electric receiver 44, which scans the optical structure 16 directly. The receiver 44 is indicated in broken lines in Fig. 2.

The multiplication stage 37 may be in the form of an analogue multiplier but may, alternatively, be in the form of either a phase-sensitive rectifier or an electronic switch or a ring modulator.

It can be of advantage to eliminate signal components containing no measurement informations, as for instance, a.c.-components, from the output signal of the signal subtractor means 36. This may be done either by way of a high-pass filter 36′ (indicated in broken lines in Fig. 2), which is connected to the output of the subtractor stage 36, or by way of two substantially identical high-pass filters 36″ which are connected in front of the stage 36 as indicated in Fig. 2.

A respective low-pass filter 20′ and 21′ may be connected as indicated in Fig. 2 behind each of the photo-electric receivers 20 and 21 to reduce the noise component of the signals applied to the inputs of the differentiating stages 32 and 33.

The optical structure means may be in the form of a physical grating structure or, for example, in the form of ultrasonic or electrical deflecting fields which perform an optical function analogous to that of a physical grating structure.

WHAT WE CLAIM IS:–

1. A process for automatically determining parallax in a stereoscopic optical system provided with movable optical structure means, the process comprising the steps of deriving two first electrical signals from optically distinguishable light fluxes received from the structure means, differentiating each of the two first signals, multiplying each differentiated signal derived from a respective one of the first signals by the respective other first signal to derive respective product signals, subtracting the respective product signals from one another to derive a difference signal, multiplying the difference signal by a reference signal related to motion of the optical structure means to derive an output signal, and applying the output signal to at least one of an indicator device for indicating the parallax and a servo-device for reducing the parallax.

2. A process as claimed in claim 1, comprising the further step of filtering each of the two first signals.

3. A process as claimed in either claim 1 or claim 2, comprising the further step of smoothing the output signal.

4. A process as claimed in any one of claims 1 to 3, comprising the further step of additionally eliminating signal components containing no measurement informations from the respective signals to be subtracted.

5. A process as claimed in any one of claims 1 to 3, comprising the further step of additionally eliminating signal components containing no measurement informations from

the difference signal.

6. A process as claimed in any one of the preceding claims, wherein the optical system comprises binocular means.

7. A process as claimed in claim 1 and substantially as hereinbefore described with reference to Fig. 2 of the accompanying drawings.

8. Apparatus for automatically determining parallax in a stereoscopic optical system provided with movable optical structure means, the apparatus comprising two photo-electric receivers to generate respective first electrical signals in response to optically distinguishable light fluxes received from the optical structure means, two differentiating devices each to differentiate a respective one of the first signals, two multiplier devices each connected to receive the differentiated signal from a respective one of the differentiating devices and to receive the respective first signal from the respective other photo-electric receiver, a subtractor device to derive a difference signal by subtraction from one another of the output signals of the respective multiplier devices, means to generate a reference signal related to motion of the optical structure means, a further multiplier device to multiply the difference signal by the reference signal, and at least one of an indicator device for indicating parallax and a servo-device for reducing parallax connected to output means of the further multiplier device.

9. Apparatus as claimed in claim 8, comprising two low-pass filters each connected to output means of a respective one of the photo-electric receivers.

10. Apparatus as claimed in either claim 8 or claim 9, comprising a signal smoothing device connected to output means of the further multiplier device.

11. Apparatus as claimed in any one of claims 8 to 10, comprising two high-pass filters each additionally connected to output means of a respective one of the first mentioned multiplier devices.

12. Apparatus as claimed in any one of claims 8 to 10, comprising a high-pass filter additionally connected to output means of the subtractor device.

13. Apparatus as claimed in any one of claims 8 to 12, comprising a further differentiating device to generate the reference signal in response to a drive signal for controlling motion of the optical structure means.

14. Apparatus as claimed in any one of claims 8 to 12, comprising additional scanning means to generate the reference signal directly in responses to motion of the optical structure means.

15. Apparatus as claimed in any one of claims 8 to 12, comprising a signal generator having first output means to provide a drive signal to control motion of the optical structure means and second output means to provide the reference signal.

16. Apparatus as claimed in any one of claims 8 to 15, wherein the further multiplier device comprises a phase-sensitive rectifier.

17. Apparatus as claimed in any one of claims 8 to 15, wherein the further multiplier device comprises an electronic switch.

18. Apparatus as claimed in any one of claims 8 to 15, wherein the further multiplier device comprises a ring modulator.

19. Apparatus for automatically determining parallax in a stereoscopic optical system, substantially as hereinbefore described with reference to Fig. 2 of the accompanying drawings.

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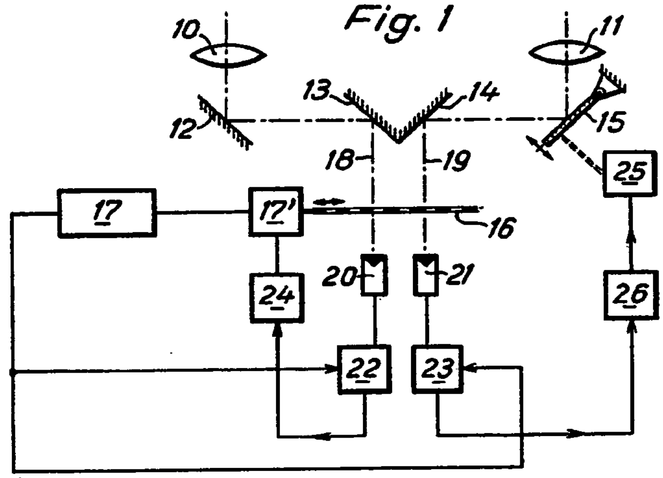
Sheet 1

Fig. 1



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Sheet 2

Fig. 2